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HALF-A-CENTURY OF CHANGE IN THE "METEOROLOGICAL SCENE"

by

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The "meteorological scene" at the beginning of our century had separate centers of activity, largely out of touch with each other. There was no world-wide communication system for weather data, and daily weather maps were of more local extent than today. The most extensive weather maps were those of the United States and Canada, although they did not at that time include the arctic territories. Europe was another area with internationally organized exchange of weather information, and the Japanese area was a third one. The weather forecasting in each area was troubled by the lack of early information about travelling disturbances from the west. It did not help the European weather forecasters, for instance, that transatlantic cablegrams could bring a daily summary of the North American weather. That had been tried in the early years of the cable connection, but then again abandoned. The Atlantic gap had proved too wide to be bridged by interpolation on the weather maps.

Upper air observations were in their first stage of development and exerted no influence on the routine of daily forecasting. Manned balloon flights were a popular public spectacle; and the measurement of the close to moist adiabatic rate of decrease of temperature with height was an important scientific by-product of such flights. Unmanned balloon flights with self-recording instruments had penetrated still higher than the manned ones, and had discovered the stratosphere.

The people on the "scene of theoretical meteorology" were becoming aware of the interesting three-dimensional structure of the atmosphere, and began to look for tools from the science of hydrodynamics that could put weather forecasting on a scientific foundation. The old German genius of natural science, von Helmholtz, had already two decades before 1900 made the first important steps with his theorems of circulation of incompressible media; and my father, V. Bjerknes, had followed up at the turn of the century by extending Helmholtz' theorems to compressible media (like air) on a rotating planet.

My first childhood memories date from this period. The tapping of the typewriter in my father's study was heard year in and year out. But then also, during summer vacations in the country, a different activity took place. Impressive kites, far greater than the toy ones, were launched, carrying recording instruments. My role was of course only to watch while grown-up students operated the kites; and the purpose of the whole thing was far beyond my comprehension. As I later learned, the kite ascents were made to extend aerological knowledge northwards from Central Europe, where many balloon ascents had taken place, to the virtually unexplored Scandinavia. In technical terms, the ascents were made to count the isobaric-isosteric solenoids in a meridional profile. The new circulation theorems called for such field work, but I must add, as most of you know, that my father's tinkering with kite technology never caused the sensation on the meteorological scene as did the circulation theorem itself.

I would like to mention a few other personalities on the "meteorological scene" in the first part of our century, and I hope you will excuse my arbitrariness in choosing these people all from Scandinavia, the only part of the world that I could observe at that time.

One of my father's students developed theorems of his own, which have found their way to all standard textbooks and forever will continue to be useful. That was W. V. Ekman, an applied mathematician who invented what all the world still calls the "Ekman Spiral". It is a symbol for the explanation given by Ekman of how friction at a boundary surface modifies the circulations derived by classical hydrodynamics for frictionless media. One of the most important applications of the Ekman Spiral is that of showing the mechanism of the maintenance of the ocean currents by wind drag at the ocean surface.

Ekman later got his appointment as a professor at the small provincial Swedish university of Lund, and remained there for the rest of his life. From his "ivory tower" came a succession of fine research contributions which built the theoretical structure from which modern oceanography got many of its present tools. As an example of the esteem of younger oceanographers for their lonely and modest senior colleague, I may mention that the young and dynamic worker, in oceanography as well as in meteorology, C.-G. Rossby, repeatedly confided to me that he had often, and very seriously, thought of abandoning all his empire-building in America in order to go back to a small job under Ekman in the provincial university in the old country.

Then, let me mention a few arctic explorers. They also belong in a description of the meteorological scene. Some were scholars in their own right, and all of them went to their adventures more or less with the moral backing of the profession of meteorology that wanted to see also the geographical frontiers of knowledge advanced. Before the turn of the century the Swedish explorer Otto Nordenskiöld had pioneered the navigation by ship from Europe to the Bering Strait north of Siberia; and the Norwegian Frithjof Nansen had been the first to cross the Greenland icecap, and several years afterwards had his ruggedly constructed ship Fram cross the Arctic Ocean following the ice drift with the trans-arctic ocean current, whose existence he had postulated. These were glamorous world events in geographical exploration, and they had pushed the frontiers of meteorological and oceanographic exploration further polewards. But more remained to be done!

Quite naturally, the manned balloon came into the picture as the vehicle that could travel faster than the ship, bring more uncharted territory under observation, and also make a beginning in exploring the aerology of the Arctic. The Swedish balloonist Andrée and two young meteorologist companions pioneered that idea, and got the necessary financial support for a balloon flight from Spitzbergen at 80°N toward the pole and beyond. The risk of failure of such a flight was great, but not really forbidding. A balloon can stay aloft long provided it does not lose gas by the periodic thermal expansion and contraction between day and night. The arctic summer does not have nights, and the balloon was expected to be able to fly there in almost constant temperature for a long time. Then also, the balloon would stay aloft long enough to be carried by the winds to some inhabited area outside the Arctic.

Such was the plan, but it failed; and the balloon with its courageous crew did never return from the Arctic.

It took thirty years for the mystery to be cleared up. An expedition of Norwegian geological surveyors in 1930 explored some uninhabited, and seldom visited, islands east of Spitzbergen. Islands that can only be reached by ship in summers of minimum volume of arctic pack ice. There they found an old camp site with the remnants of the Andrée expedition. The diary and the meteorological log were found in good readable shape, so that the following thirty year old happenings could be reconstructed:

All had gone well to begin with, and the balloon had travelled at low altitude about one third the distance to the North Pole, when the wind dropped to a light breeze of variable direction. During that period the rope, that was being dragged behind the balloon to afford some amount of steering, got stuck around the corner of an ice hummock, whereafter the balloon remained helplessly moored to the ice. After a period of desperate waiting the balloonists had to release gas, and land.

The tour back, on foot across the rough ice and in a raft across open lanes, was a terrible struggle, and it ended at the uninhabited island from which no further southward push was possible.

This was only one of the many tragic losses of young arctic explorers volunteering to take great personal risks in the service of science. I only mention the Andrée tragedy because it was very much part of my childhood scene. One of the balloonists was my father's student in Stockholm, Sweden.

Today, as we all know, flying has conquered the Arctic. Regular long distance passenger flights connect Europe with Alaska and the Far East by way of the North Pole, and meteorological and oceanographic observing platforms with comfortable living quarters are maintained on drifting arctic ice floes. The air freight logistics for such scientific activity is not entirely free of risk, but the risk factor is what we in modern thinking call "acceptable"; and, certainly, it is several orders of magnitude safer than the Andrée arctic balloon flight.

Today the glamorous, and risky, frontier of exploration is space; and again young enthusiasts volunteer for it. "Space" is outside the atmosphere, and space science is not meteorology. But we as meteorologists are not quite free of responsibility for the space billions this country is spending. Listen to this quotation from one of our leading politicians: "How can we be second in space, and first on earth? These people who discount the importance of the race to the moon never cease to astound me. Suppose the Russians conquered space first? Suppose they began determining the weather, and turning America into an arid plain? No, you can't be first on earth and be second in space."

Within this A.M.S. forum let it be said that over-eager space enthusiasts unintentionally must have misinformed the political leaders of our country. No meteorologist in his right mind would claim that from space American climate can be turned into aridity.

Less extreme misconceptions are often heard from the space scientists themselves. The usual theme is: when we get space platforms all the problems of weather forecasting on earth will be trivial and easy to solve. Even such statements should in our own interest be emphatically contested. Space platforms, even manned ones, we shall probably get in a not too distant future. But faultless weather forecasting will not follow. And meteorologists will then be blamed for not being able to perform the "trivial" job of turning the information from a space platform into perfect short and long-range weather forecasts.

Now, don't misunderstand me as being entirely anti-space. I am not. Tiros satellites were marvelous eye-openers for synoptic meteorologists myself included; and our world-monopoly on these wonderful gadgets is a source of world prestige of which we can be justifiably proud. But let us not lose our balanced view of what scientific weather forecasting really is: 1) a quick compilation of data on the present state of the global atmosphere, and 2) a quick prediction of the change of that state by time-integration of our dynamic equations. Ultraviolet, visual, and infrared observations from a space platform would help to some extent under heading (1), but hardly at all under heading (2). Even in the job of compiling the present state of the atmosphere I would not trade our reporting weather ships against satellites on a dollar for dollar basis. To reap the benefits from modern numerical forecasting we do need weather ships, and more of them, particularly in the Pacific Ocean. Satellites do not make weather ships superfluous.

Well, what should we recommend our bright young students to do with their careers on the present "meteorological scene"? I would exclude the glamorous trip to the Moon, and even that to Mars. Our meteorology on Earth is infinitely more important for mankind, and we need all the bright young people right here. There is plenty of choice of subjects. On the meteorological scene of today we are "teaching more and more about less and less"; meaning that more and more fields of narrow specialization, too numerous to be mentioned here, are available for choice. Modern society calls for all that differentiation, and I hesitantly admit that most of that diversification is inevitable.

But yet I would give highest recommendation to the less narrow and more basic field of meteorology, which was the concern of the founders of our science, and which still is our first duty to society: <u>weather forecasting</u>. All too frequently, students, and professors too, shy away from the subject of weather forecasting and go into one of the nice little research specialties which are less nerve racking, and which do not force you to show the public how often you are wrong.

But, fortunately, the weather forecaster will soon be better off.

Electronic automation has already relieved him of much of the overwhelming load of data handling, and now also presents him with electronically computed forecast maps. True enough, these forecast maps are not infallible, because they apply strictly only to a "model atmosphere" which is a simplified version of the real atmosphere. But the computed forecast maps do have the great merit of being consistent with the teaching of the science of fluid media, which in turn is safely tied to mathematics. And, with that sound foundation, improvements are bound to come to the still very young science of numerical forecasting.

But such progress will be contingent upon the alertness, intuition, and creative thinking of the men who use the computers. They must not gullibly accept all that is turned out by the computers. They must scrutinize the errors of the machine forecasts, and step by step they will have to teach the computers to do an even better job than that of today. That challenge certainly ought to attract many of the bright young men who are to choose a career in meteorology.

Since the A.M.S. has given me this unique opportunity of addressing a large and representative professional audience, I cannot resist the temptation to wind up with a plug for the combined oceanographic-meteorological research, to which I am devoting my last active years. It is quite logical to enter that field if you want to understand the changes of weather over longer range; in other words: the "climatic change". In short-range forecasting, the oceans can be considered a constant lower environment of the atmosphere with a time-constant field of temperature; but in long range forecasting, the changing anomalies of ocean temperature cannot be overlooked, because they decide the rate of heat and humidity supply to the atmosphere (for any given wind velocity). The study of the interacting climatic anomalies of the atmosphere and the oceans is therefore a "must" if we are to understand the mechanism of climatic change.

The period of adequate marine observations for such studies extends about 80 years. In the National Weather Record Center, in Asheville, N.C., 33 million ship observations are now stored, and the stockpile rapidly grows from year to year. Individual researchers of course cannot cope with the gigantic job of extracting all the useful information from that many millions of observations, and the science of ocean-atmosphere interactions has therefore largely stagnated after a brief blossoming period in the early part of our century. But on the modern meteorological scene the fast electronic processing can salvage the stored treasures of information, and soon will do so, if the latest nationwide plans for the research on air-sea interaction get implemented.

Fortunately, the past 80 years have also seen a good deal of measurable climatic change, so that much can be learned from a study of that important period. The geographical models of climatic anomalies found to apply for the recent past will also help us to evaluate the many different theories put forth for the more distant past, in particular those of the ice ages.

We can enter this type of research armed with the knowledge contained in the theorems of circulation of atmosphere and ocean handed down to us from the primitive meteorological scene of half-a-century ago. But it is fitting and timely at this occasion also to remember how much was later added in the way of important tools for ocean-atmosphere research by the late Harald Ulrik Sverdrup; whom we are honoring today.

Dr. Sverdrup came from the same theoretical school as did his senior Swedish colleague in oceanography W. Ekman, but Sverdrup's career unfolded more on the international plane, first as a Norwegian arctic explorer, then as a U.S. citizen in the directorship of the Scripps Institution of Oceanography, and finally back to international work in the old country. Among his many fine research contributions we here only mention one of his last, from 1947, which, by an ingenious combination of the circulation theorem and Ekman's theory of wind drift, gave us the simple rules for long-range adjustment of ocean currents dictated by primary meteorological change. The resulting, usually minor, adjustment in ocean currents has, in turn, a perceptible feed-back effect on the atmospheric circulation, whereby the play of climatic change, in atmosphere and oceans, continues through decades, centuries, and millennia.

It will obviously take a long time to get a firm hold on the theory of current climatic changes through verification testing by observations. But it seems to be a safe prediction that the A.M.S., when reviewing the state of knowledge on the processes of climatic change some time in the 21st century, will feel proud that in 1964 the name of Harald Ulrik Sverdrup was immortalized also by the institution of an A.M.S. gold medal.